CERTIFICATE OF MAILING/TRANSMISSION (37 C.F.R. 1.8A)

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Date: 12 March 2007

Signature

Lisa L. Pringle
(type or print name of person certifying)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:	)
	)
Ian Robinson, et al.	) Group Art Unit: 2611
	)
Serial No.: 10/689,275	)
	)
Filed: October 20, 2003	) Examiner: Julia P. Tu
	)

For: *Systems and Methods for Signal Conversion*

DECLARATION UNDER 37 C.F.R. §1.131

Sir:

I, the undersigned, declare as follows:

1. I, Ian Robinson, am an inventor of the invention entitled Systems and Methods for Signal Conversion, disclosed and claimed in U.S. Patent Application Serial No. 10/689,275 (hereinafter to as "the Application"), which was filed on October 20, 2003.

2. I along with my co-inventor, Frank Winter, conceived the subject matter that is disclosed and claimed in the Application prior to July 23, 2003, while employed by the Assignee.

3. I submit that an invention disclosure, presented in redacted form as Exhibit A, was written and submitted to Lorna L. Schott, Patent Administrator for Northrop Grumman Space & Mission Systems Corp. Space Technology, prior to July 23, 2003, and thereby establish conception and support of at least the systems, methods, and devices recited in claims 1, 13, 19, and 26, prior to July 23, 2003. Specifically, Figure 2, on page 11, the first two paragraphs of page 6, and the discussion of Figures 5a through 5d support these claims.

4. On October 1, 2003, Christopher Harris contacted me via e-mail to request that I review a draft of the application for technical accuracy and completeness. The e-mail included an electronic copy of a draft of the Application. The e-mail is attached hereto as Exhibit B. A copy of the draft of the Application is attached hereto as Exhibit C.

5. At some time prior to October 7, 2003, I sent an e-mail to Christopher Harris containing my comments and revisions regarding the draft of the Application.

6. On the morning of October 7, 2003, Christopher Harris provided a revised second draft of the Application via e-mail. A copy of that email is attached hereto as Exhibit D.

7. In the afternoon of October 7, 2003, I responded to Christopher Harris by e-mail with some final changes and approved the draft Application subject to those changes. A copy of that e-mail is attached as Exhibit E.

8. On October 14, 2003, I received electronic copies of the Application and a set of formal papers via e-mail from Christopher Harris. A copy of that e-mail is attached as Exhibit F. I signed the formal papers confirming that I am a coinventor of the invention described in the Application and assigning my interest in any patent granted from the Application to Northrop Grumman Corporation. I then promptly mailed the signed papers back to Christopher Harris for submission with the Application.

9. I believe that the Application was filed in the U.S. Patent Office on October 20, 2003.

10. I declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under §1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Ian Robinson

March 8, 2007
Date

Serial No. 10/689,275 Docket No. NG(ST)-6583

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:	)	
	)	
Ian Robinson, et al.	)	Group Art Unit: 2611
	)	
Serial No.: 10/689,275	)	
	)	
Filed: October 20, 2003	)	Examiner: Julia P. Tu
	)	
For: *Systems and Methods for Signal Conversion*		

DECLARATION UNDER 37 C.F.R. §1.131

Sir:

I, the undersigned, declare as follows:

1. I, Frank Winter, am an inventor of the invention entitled Systems and Methods for Signal Conversion, disclosed and claimed in U.S. Patent Application Serial No. 10/689,275 (hereinafter to as "the Application"), which was filed on October 20, 2003.

2. I along with my co-inventor, Ian Robinson, conceived the subject matter that is disclosed and claimed in the Application prior to July 23, 2003, while employed by the Assignee.

3. I submit that an invention disclosure, presented in redacted form as Exhibit A, was written and submitted to Lorna L. Schott, Patent Administrator for Northrop Grumman Space & Mission Systems Corp. Space Technology, prior to July 23, 2003, and thereby establish conception and support of at least the systems, methods, and devices recited in claims 1, 13, 19,

and 26, prior to July 23, 2003. Specifically, Figure 2, on page 11, the first two paragraphs of page 6, and the discussion of Figures 5a through 5d support these claims.

4. On October 8, 2003, I received electronic copies of the Application and a set of formal papers via e-mail from Christopher Harris. A copy of that e-mail is attached as Exhibit G. I signed the formal papers confirming that I am a coinventor of the invention described in the Application and assigning my interest in any patent granted from the Application to Northrop Grumman Corporation. I then promptly mailed the signed papers back to Christopher Harris for submission with the Application.

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Frank Winter

3/8/2007
Date

EXHIBIT

A

TRW

Invention Disclosure Form – Part 1

Jump to:

Invention Title and Date of this Disclosure Form

Docket: *(Patent office use only)*

Date: March 16, 2003

Title of Invention: High Dynamic Range Receiver

Conception of Invention

Date of First Written Description of the Invention: February 3, 2003

Identify the Written Description and Indicate Where Located:

Date of the First Oral Disclosure:		To Whom:	Conversation Between Ian Robinson and Frank Winter
Date of First Sketches or Formal Drawings:	February 6, 2003	Present Location of Sketches or Drawings:	Hard drive of inventor

☐ Drawings

(Please Obtain All Signatures Before Sending to Lorna Schott, Intellectual Asset Management)

Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
Witnessed, Read and Understood by:		Witness:	Date:	Supervisor:	Date:

Construction And Test Please attach a copy of any dated test reports (or relevant portions).

Invention Simulated / Modeled? in part	Yes ☐	No ☒	Date:	
			By Whom:	
Invention Physically Constructed?	Yes ☐	No ☒	Date:	
			By Whom:	
Invention Successfully Tested?	Yes ☐	No ☒	Date:	
			By Whom:	

Contract or Project Information

The Invention First **Conceived** While Charging Time to Job No.: 94KKAC

And Working On:

Government Contract or Subcontract No.: ______ Title: ______

TRW Funded (IR&D, B&P, PM&P) Project No.: 02412007 Title: Universal Base Transceiver Station

Commercial Contract Name or Number: ______ Customer: ______

Other: ______

Contract Administrator and Phone No.: ______

The Invention First **Constructed** While Charging Time to Job No.: ______

And Working On:

Government Contract or Subcontract No.: ______ Title: ______

TRW Funded (IR&D, B&P, PM&P) Project No.: ______ Title: ______

Commercial Contract No.: ______ Customer: ______

Other: ______

Contract Administrator and Phone No.: ______

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Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
Witnessed, Read and Understood by:		Witness:	Date:	Supervisor:	Date:

TRW

Offer For Sale

Was invention disclosed to a non-TRW employee in the course of negotiation or execution of a sales transaction, or is such a disclosure imminent? Yes ☐ No ☒

Is it anticipated that an activity will occur soon? Please provide the appropriate information below and enter expected date. Yes ☐ No ☒

(If no, continue to Public Use section)

Date of First Executed Sales Contract: ________

Identify First Sales Contract No.: ________

Date Of First Delivery To Customer: ________

Was Invention Described in a Proposal?	Yes ☐	No ☐	Date:
Was a Description of the Invention Provided to the Government?	Yes ☐	No ☐	Date:
Was a Description of the Invention Provided to a Commercial Customer?	Yes ☐	No ☐	Date:
Was a Description of the Invention Provided as Part of an On-going Contract?	Yes ☐	No ☐	Date:

If you answered YES to any of the above questions, please provide a copy of the material which included the description.

Public Use

Has the invention been used in a public setting? Yes ☐ No ☒

If the invention is a manufacturing method or machine, has the invention been used to produce products delivered or deliverable to a customer? Yes ☐ No ☒

If the invention is a product, has the product been delivered to someone outside TRW? Yes ☐ No ☒

If you answered YES to any of the above questions, please provide details.

Publication

Has a Description of the Invention Been Published or Described in a Customer Report? Yes ☐ No ☒

If Yes, *Provide a Copy* and Identify Publication by Name, Customer, Date, and Number:

Did the Customer Report Have a TRW Proprietary Legend? Yes ☐ No ☐

Has the Invention Been Described to People Not Employed by TRW? Yes ☐ No ☒

If Yes (A) Was Disclosure Under a Confidential Disclosure Agreement?

(B) Provide Names of Person(S), Their Employers(S), Date, and Place of Disclosure:

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Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
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TRW

Prior Art Reference Material

Identify Any Prior TRW Invention Disclosures, Patent Applications, or Issued Patents Relating to the Invention: (Provide TRW Docket No. or Patent No. if Available)

NG dockets 000294-804 *Improved System For Distribution and Reception of Signals and*

000288-804 *Improved Handoff and Initiation System in Mobile Communications*

TRW Docket 48-0045 *High Speed Digital Synthesizer*

Technical Evaluation:

Please enter codes corresponding to ALL technology areas that you believe describe your invention.

3, 4, 5, 10, 16

Category	Code	Category	Code
Antennas	1	Military	10
Automotive Electronics	2	Miscellaneous	11
Avionics	3	Photonics	12
Communication Systems	4	Satellite Communications	13
Electronics	5	Semiconductors	14
Energy Systems	6	Sensors	15
Lasers	7	Space	16
Materials	8	Superconductors	17
MEMS	9		

What was the problem or need that you were trying to solve?

Develop a multi-carrier GSM receiver. GSM receivers must operate in the presence of blocking signals as much as 88 dB above the wanted signal level (WSL).

Inventive Concept – What is new, what it does and how it does it?

The present invention is novel in that is has not been described in any publication, known patent, or known patent application. It reduces the required dynamic range of receiver components by mixing the signal at RF or IF with a direct sequence or frequency hopping spreading code prior to input to an analog-to-digital converter (ADC). After ADC execution, the digital data is mixed with the same spreading code to recover the wanted signals. Signals will occupy greater bandwidth after spreading but with overall lower dynamic range in any given spectral band. The digital processor has knowledge of the spreading code employed and can de-spread the data prior to detection. It can use a correlator to align samples in time with the de-spreading code.

The present invention trades bandwidth for dynamic range in receivers. In some receivers (e.g. single carrier systems or WCDMA) the system bandwidth is well match to the instantaneous signals. In other systems (e.g. multi-carrier GSM or TDMA systems) the receiver bandwidth is sized to cover a broad range of possible signal locations.

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For communications systems with one or more narrowband in a given bandwidth, the application of spreading codes more evenly distributes their power density across the receiver band (there was no wanted signal power in between the signals prior to spreading). In this case the receiver bandwidth is not impacted as it was already sized to cover the possible locations of carriers.

In a communications where signals cover the nominal bandwidth of the receiver spreading increases the required bandwidth but similarly reduces the dynamic range requirement.

The entire signal chain is impacted by reducing dynamic range and by a possible increase in required bandwidth. The component most heavily impacted is the analog-to-digital converter (ADC). Recent trends in these devices see improved speed, which translates to bandwidth, but little if any improvement in dynamic range for wideband devices. This is due, at least in part, to the noise floor of the devices employed and the magnitude of spurious signals created because of the difficulty in matching device characteristics precisely.

There is a significant drop in price/difficulty in production of ADCs for cellular standards when the dynamic range requirements are reduced by 10 dB with additional significant savings for an additional 10 dB relaxation.

Accordingly, the present invention seeks to attenuate the strong interfering signals by at least 10 dB (with 20 dB desired) or more. It performs this reduction by creating a spreading code, converting it to IF or RF, and mixing it with the incoming signals (at IF or RF, respectively). The spreading must increase the wanted signal bandwidth by at least the desired amount of dynamic range reduction.

For GSM signals occupying a 200 KHz band a 10 dB increase would spread them to 2 MHz and a 20 dB increase to 20 MHz. TDMA signals occupying a bandwidth of only 25 MHz can be spread to even greater levels.

The spreading function has another benefit that is included in the forthcoming disclosure *Improved System For Distribution and Reception of Signals*. Using two or more mutually orthogonal spreading codes, as are routinely used in spread spectrum systems, signals received by two or more antennas can be combined and then processed by a single ADC and digital processor.

Invention Description and Operation: (Attach drawings or sketches, if available)

The present invention was conceived of to operate in the GSM900 band where a CW blocking signal may be 88 dB above the wanted signals and within 3 MHz of the wanted signals. The present invention will improve the sensitivity or enable sensitivity with lower performance, lower cost components for any receiver operating in an interference environment.

Figure 1 shows a standard receiver circuit designed to capture wideband GSM data, wanted signals and unwanted interference or blocker signals. In some receivers a second down conversion stage is needed as available ADCs provide higher dynamic range at lower IF. The prior art picture could be for either single carrier receivers or multi-carrier receivers. Multi-carrier receivers can replace single carrier receivers in many applications with more compact, lower cost per carrier components. Multi-carrier receivers can also expand the number of signals received for almost no cost.

The present invention reduces the dynamic range requirement of a receiver's ADC and other components by spreading the incoming signal over a wider bandwidth, decreasing power spectral density by the

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spreading ratio (wanted signal bandwidth to spread signal bandwidth).

Figure 2 shows the addition of a mixer that multiplies the wanted signal, shown at IF, with a binary signal of much higher bandwidth. The binary signal can be one of many standard spread-spectrum direct sequence codes and is generated in the digital logic. It is passed through a low dynamic range, low cost DAC. The spread signal is digitized and then is de-spread, using a copy of the spreading signal, in the digital logic. The digital logic may use a correlator function to align the spread signal with its code. The de-spread signal is channelized and/or sent to detection functions.

A spreading code is generally a noise-like psuedo-random signal. There are several families of mutually orthogonal codes that can be used to separate signals in a common band or on one carrier.

Not shown is an alternate method of spreading the wanted signal. Either at RF (replacing the fixed LO shown in Figure 2) or at IF (replacing the spreading code as shown) this alternate would employ a fast-settling synthesizer. Rapidly hopping a frequency conversion oscillator using a spreading code to determine the sequence of frequencies is a viable spreading mechanism. Using the invention described in TRW Docket 48-0045 settling times of a few nanoseconds are possible enabling spreading of unto hundreds of megahertz.

Figure 3 depicts the change in power spectral density for a single wanted signal. For a single carrier the present invention trades dynamic range for bandwidth performance in the receiver. Spreading increases bandwidth while reducing dynamic range in any spectral interval. Figure 4 depicts the result of spreading several narrowband signals in a band of interest. In the case shown, the spreading function is wider than the spacing of the original carriers. The original signals and spacing will be recovered after digitization and despreading.

Multi-carrier receivers must cover the entire spectral range where wanted signals may be found. For example 880-915 MHz is the GSM900 receive band. When four carriers, each 200 KHz, are used most of the spectrum is empty or contains only noise and interference. Other wireless bands may span 75 MHz or more. Thus, significant spreading can be applied without increasing the overall receiver and ADC bandwidth.

The ADC and other receiver components of a multi-carrier receiver must cover bands (e.g. 25-75 MHz for GSM signals) much wider than a single wanted signal (200 KHz for GSM) while providing adequate dynamic range for both wanted and uncooperative signals. Applying the spreading code lower power density, with spread signal power filling in the previously unused spectrum across the band (see Figures 5a and 5b).

The sequence of Figures 5a through 5d describes a sensible application of the present invention. In the example shown four carriers, each 200 KHz wide, are to be received. There is also a very large blocking signal in the receiver band that covers 890-915 MHz. The wanted signals may be as much as 88 dB lower powers than the blocking signal. The combination of noise sources, dominantly the ADC quantization noise and the phase noise of the large blocking signal drive the ADC to ~106 dB dynamic range as measured in the wanted signal's 200 KHz bandwidth (BW).

Figure 5a shows the peak input signal is the blocker at –13 dBm or 13 dBm/BW, where BW is the wanted signal bandwidth of 200 KHz. The wanted signals are at –101 dBm (also in 200 KHz). To ensure that the

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ADC noise is small compared to the signal, as required to provide high Eb/No in the presence of other noises, it is set at –119 dBm/BW. This noise is 18 dB below the wanted signals in a 200 KHz bandwidth. The difference in the peak input signal and the noise level determines the ADC requirement for dynamic range of ~106 dB.

Figure 5b shows the signals and the blocker after they have been spread by a 6 MHz code. 6 MHz is 30 times wider, or 15 dB, the original signals. The power density of the wanted signals and the blocker are reduced 15 dB in a 200 KHz bandwidth. This figure shows the dynamic range requirement of the ADC reduced by 15 dB, the same factor as reduction in power spectral density due to spreading (the spreading factor).

Figure 5b shows the result of applying a 6 MHz wide spreading code. Each signal and the blocker occupy approximately 6 MHz after spreading. Figure 5c is the same as 5b but where all the signal levels have been adjusted assuming an additional 15 dB of gain is applied at the receiver input.

Figure 5d shows the result of de-spreading the digitized data. The carriers and blocker signal are restored to their original bandwidths. Even if the spreading function had caused these signals to overlap the de-spreading function will recover the signals in their original bandwidths with their original spacing. Going from 6 MHz to 200 KHz, the wanted signals are amplified by "spreading gain"; 15 dB in this case.

The noise from the ADC however is, to first approximation, unaffected by the de-spreading process. Thus the signal-to-noise ratio in a 200 KHz bandwidth improves by the spreading gain following the de-spreading function. Accordingly, the ADC dynamic range requirement is reduced by the spreading gain compared to a prior art configuration. The spreading gain is present for the wanted signals because they are correlated with the de-spreading code. The noise is not normally correlated with the spreading code (generally a noise-like pseudo-random signal). Thus mixing them together results in no change, from either correlation or anti-correlation, to the noise.

The example provided is for illustration of the concept. The invention can reduce dynamic range requirements for ADCs, both conventional and delta-sigma or noise-shaping converters. The greater the bandwidth of the spreading function the greater the reduction in dynamic range requirements. It is useful to balance the bandwidth and dynamic range requirements of the receiver in setting the spreading factor.

Not shown is a second embodiment where the spreading code is upconverted to RF and applied on the same carrier used to downconvert the wanted signals. This is an option that saves one mixer and LO but could cost somewhat more to produce the spreading signal. Using a Northrop-Grumman delta-sigma DAC the spreading signal could be cost-effectively produced at IF or RF.

In a third embodiment, the present invention can be used to trade bandwidth for dynamic range in the opposite direction. It can be used to de-spread signals that have been spread by their transmitter. This embodiment might require an additional filter in the receive chain to remove images. It would enable reception of a spread spectrum signal with a low bandwidth receiver.

The other important aspect of de-spreading is synchronizing the spread signal with the de-spreading code. In digital spread-spectrum systems many phasings of a code can be tested in parallel to converge on timing. Using an analog de-spreading function would allow only a single code phase to be tested at one time.

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Some provision for iteration and sliding the code phase would need to be made.

Briefly describe what the prior art taught:

Prior art has taught how to receive all the wanted signals in their provided bandwidth. In one example of prior art (e.g. NG's RANGER program) narrowband receivers are tuned to the center frequency of wnated signals and analog filtering is used to minimize interference. Prior art multi-carrier receivers (as developed by the UBTS program), the dynamic range of the system was sized to detect very small wanted signals in the presence of large interfering signals. The noise floor of each component in the receive chain had to be minimizes, especially ADC quantization noise.

De-spreading is routinely employed for spread spectrum systems. In these systems the transmitter spreads signals prior to the air interface. At the receiver, signals generally digitized and de-spreading is employed along with time correlation and special processing for multi-path signals. There are many benefits to the overall system as spreading bandwidth is increased. One of the limitations of such systems is the bandwidth required on the receiver ADC. The present Invention would alleviate that problem, recovering the original unspread signals. Some care would be required on the transmission side to avoid overlap in the recovered signals.

Until recently, wide bandwidth and high dynamic range receivers were used only for specialized applications. The expansion of numerous wireless commercial applications has created a growing demand for more of both bandwidth and dynamic range.

What are the advantages to your invention (performance, cost, enabling new characteristics, etc)?

The present invention enables lower cost digital receivers or higher performance receivers given the same components. In recent designs for multi-carrier GSM and WCDMA base station receivers up to half of the component cost was the very high dynamic range ADC. This fraction of cost due to ADC was higher if two or more antennas were employed for diversity reception.

For the most stressing GSM interference environments, ADC components are not available with the required/desired dynamic range. In some other cases the only ADCs with ample dynamic range operated at low IF, necessitating two stages of downconversion to supply a frequency commensurate with these ADCs. The dual conversion designs adds cost and lowers performance due to in-band spurs. Figure 6 shows representative trends in ADC cost at high and low IF levels.

The present invention will enables designs with lower cost ADCs running at higher IF. In some cases ADCs will be able to run at RF, obviating the need for any frequency conversion to be performed (though a mixer will still be needed to apply a spreading code).

Each of the first two embodiments reduces the dynamic range of the ADCs by significant amounts (20+ dB possible for GSM), reducing the cost of required ADCs cost by 60-90%.

At present ADCs cannot be made in volumes with performance levels that satisfy the GSM900 requirements. The present invention would enable lower cost and performance ADCs to be used in multi-carrier receivers in this band.

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A multi-carrier receiver can increase the number of carriers received by extension of the only digital logic and backend data capacity. Single carrier receivers must be replicated for each new carrier and additional splitting must be performed to bring signals from each antenna to a receiver.

Recent cost comparison showed that for GSM systems a multi-carrier receiver could be made for twice the price of a single carrier receiver. Thus, a four-carrier receiver could be produced for half the price of four single-carrier receivers. With a 20+ dB reduction or more in dynamic range enabled by the present invention, the multi-carrier receiver can be made for roughly the same price as a single carrier receiver.

In the GSM case described, spreading will not increase the receiver or ADC bandwidth. Thus either a lower performance conventional ADC can be used or a delta-sigma ADC of reduced filter order and complexity. In the case of a delta-sigma ADC, a chip of comparable real estate could be configured with different filter loops to provide wider bandwidth at reduced dynamic range (instead of 25 MHz at 106 dB dynamic range, 75 MHz could be supplied at 95 dB dynamic range). With spreading the reduced dynamic range would be adequate and the wider range could cover either a wider band of interest or could be employed to receive signals from more than one antenna (see Docket 000294-804).

The cost of the implementing the spreading function will be small if delta-sigma DAC and/or digital synthesizers are employed.

In cases where the overall receiver bandwidth is increased by the spreading function there is still benefit where conventional ADCs are employed. Such ADCs have roughly a constant noise floor from DC to their Nyquist sampling frequency. Thus they are inherently wideband. Reducing their dynamic range requirement allows a part to be used with fewer effective bits.

If a delta-sigma ADC (DS ADC) is used in a receiver then increasing bandwidth for lower dynamic range requires a different DS ADC. In the case of GSM systems we are attempting to build a 10th order DS ADC to provide the very high dynamic range over 25 MHz of instantaneous BW. 20 dB of spreading gain would allow us to use a much smaller 6th order DS ADC or perhaps even a less complex one. It also would allow us to find low cost, off-the-shelf conventional ADCs. If for example the system bandwidth had been increased to 60 MHz from 25 MHz by spreading then a similar DS ADC could have been made with different filter loops and perhaps lower complexity.

The present invention is beneficial when the receiver bandwidth is not appreciably increased for any ADC, anytime conventional ADCs are used (or can be used when spreading is employed), and may be beneficial when bandwidth is increased and DS ADCs are employed.

The cost benefit for multi-carrier receivers has historically been a benefit in the per carrier cost. For those parties, such as Northrop-Grumman, who have an interest in seeing multi-carrier technology deployed, this invention may be a business enabler. Many base stations are deployed with only one or two carriers initially. They are expanded later to include additional carriers as capacity demands increase. Service providers are reluctant to pay additional costs upfront at the time of deployment for multi-carrier receivers even though eventually they provide a lower cost per carrier. The present invention reduces cost of a multi-carrier receiver sufficiently to tilt the business case for the deployment of multi-carrier systems.

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Multi-carrier receivers are an enabling technology for the Docket 000294-804 *Improved System For Distribution and Reception of Signals* and NG Docket No. 000288-804 *Improved Handoff and Initiation System in Mobile Communications*. These two disclosures describe significant performance enhancements for base stations, partially based on the availability of wideband ADCs with adequate dynamic range to manage the wanted signals and interference environment.

Are there practical alternatives to the system, structure or method of the invention? That is, how easy would it be to design around the claimed invention?

No apparent alternatives are obvious.

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TRW

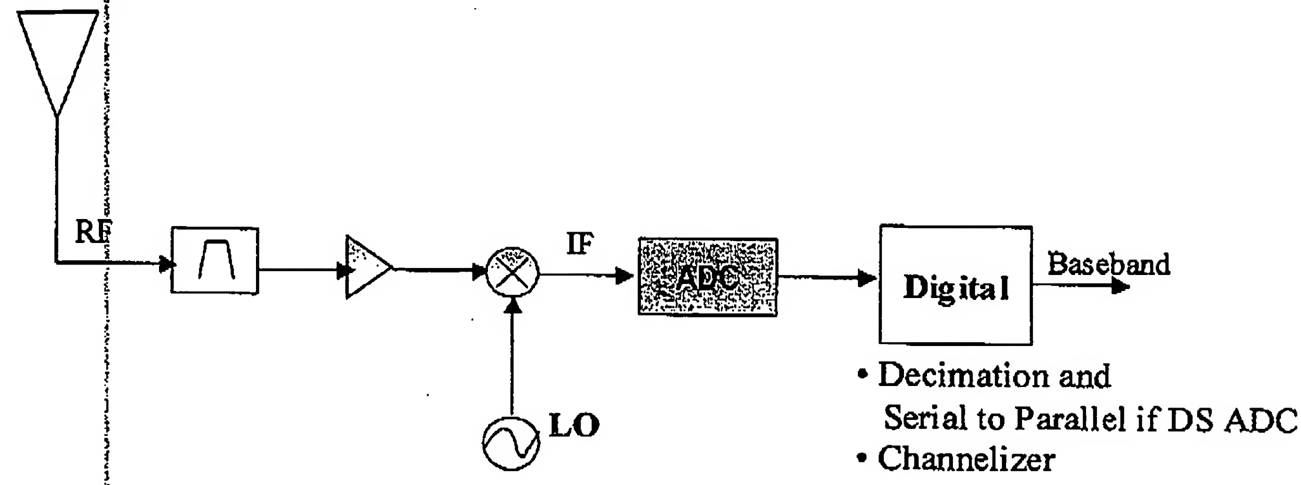

Figure 1: Prior Art Single Conversion Receiver

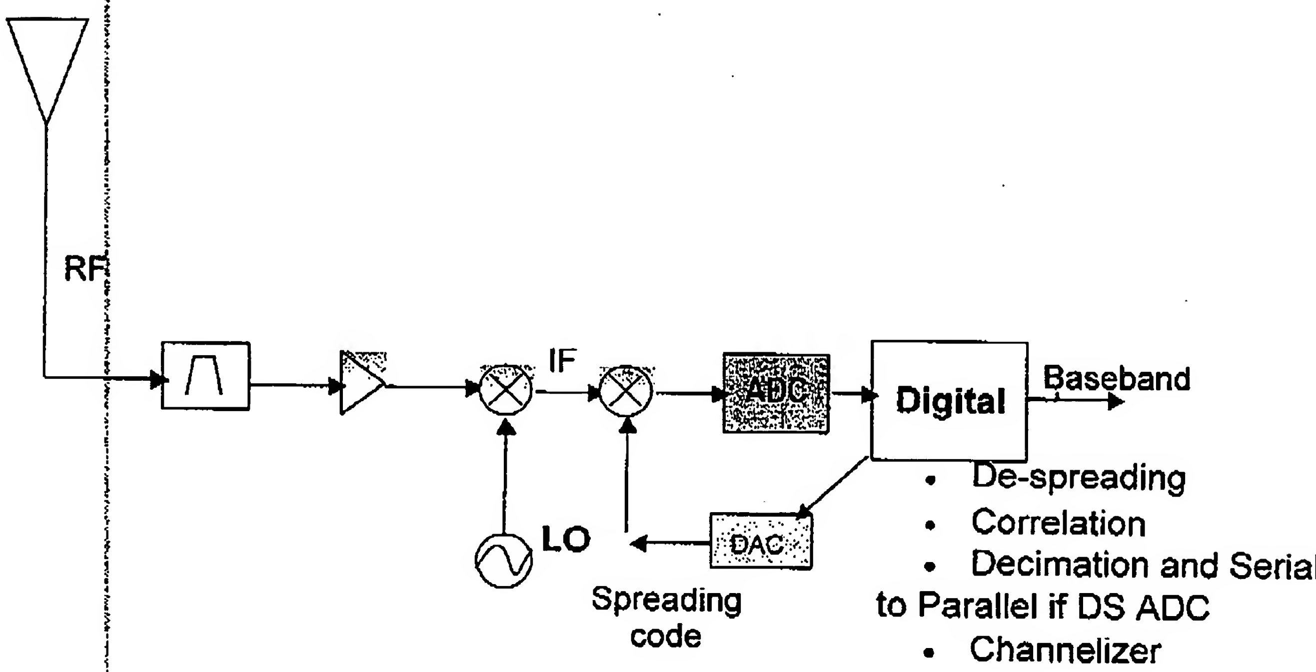

Figure 2: First Embodiment

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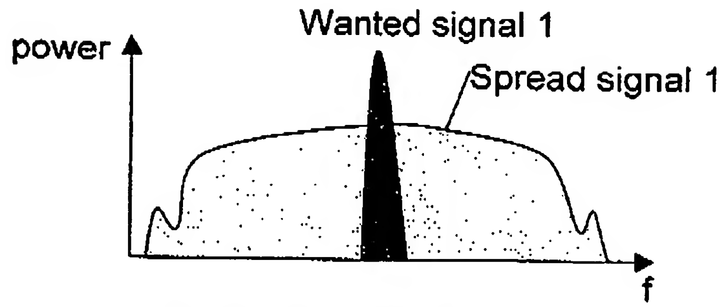

Figure 3: Single Signal With Spreading

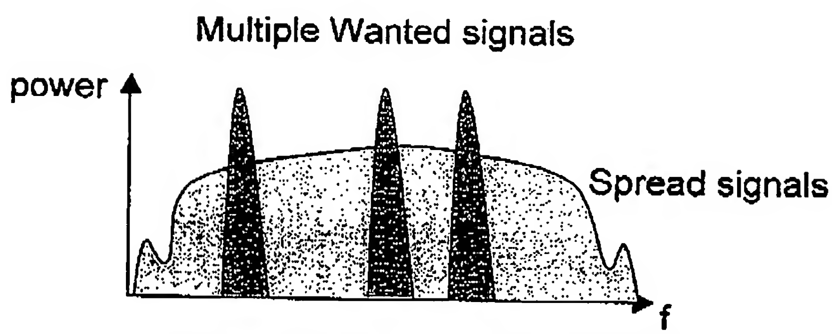

Figure 4: Multiple Signals With Spreading

(Please Obtain All Signatures Before Sending to Lorna Schott, Intellectual Asset Management)

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Witnessed, Read and Understood by:	Witness:		Date:	Supervisor:	Date:

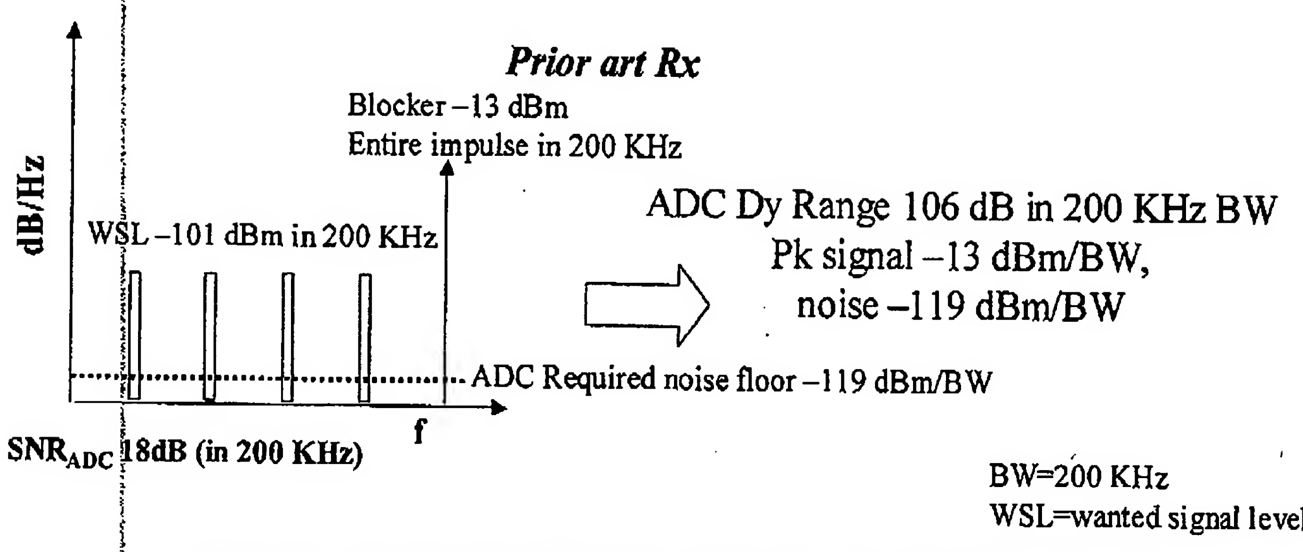

Figure 5a: Example of Required ADC Dynamic Range for Prior Art GSM System

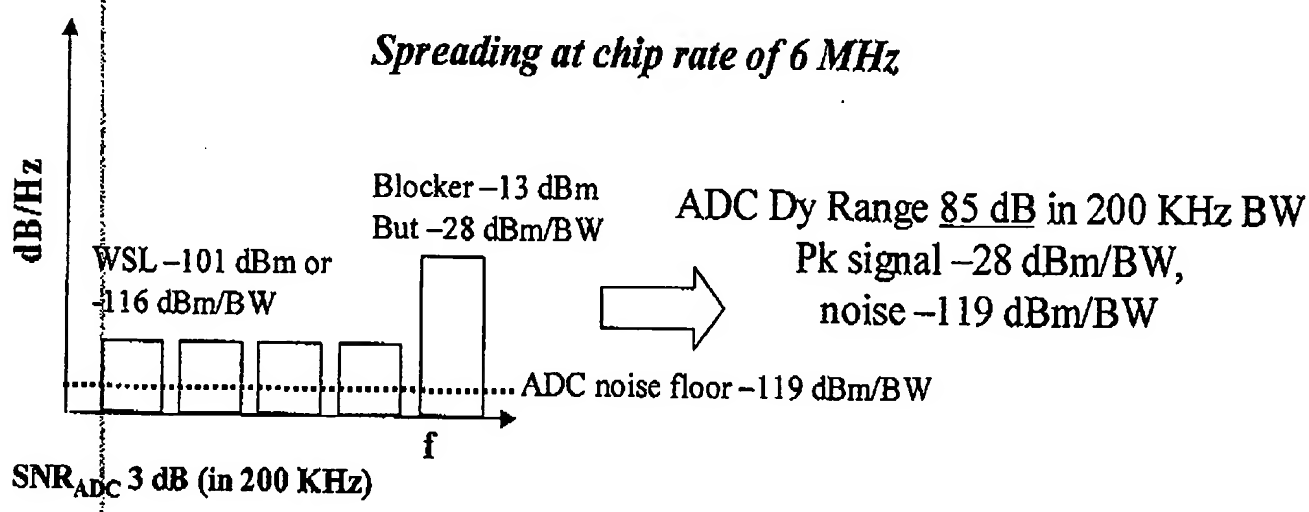

Figure 5b: Example of Required ADC Dynamic Range for Present Invention with GSM

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Witnessed, Read and Understood by:	Witness:		Date:	Supervisor:	Date:

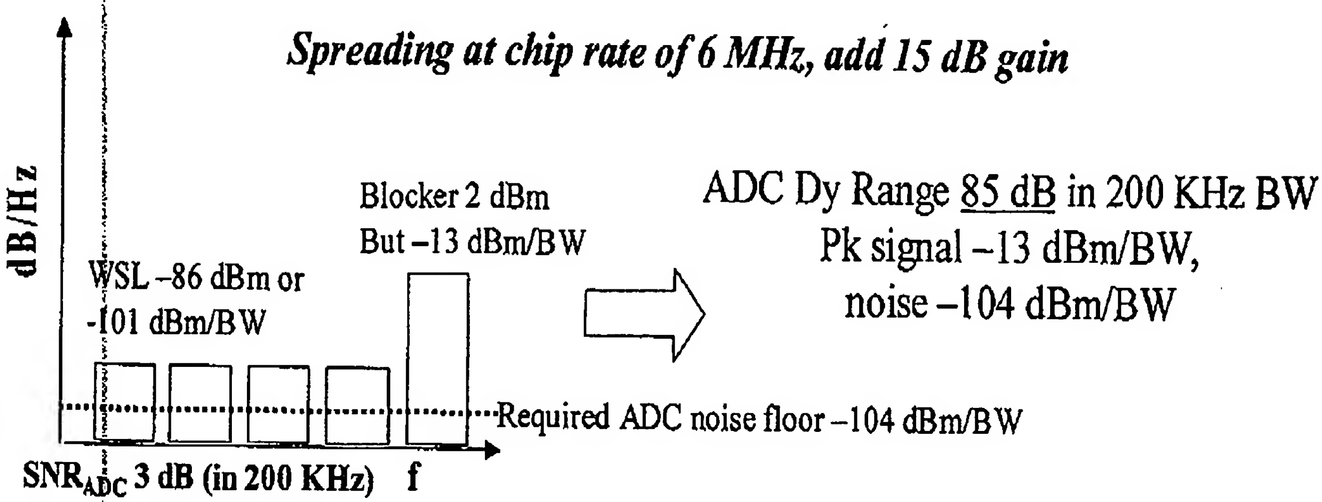

Figure 5c: Example of 5b with 15 dB gain added at LNA

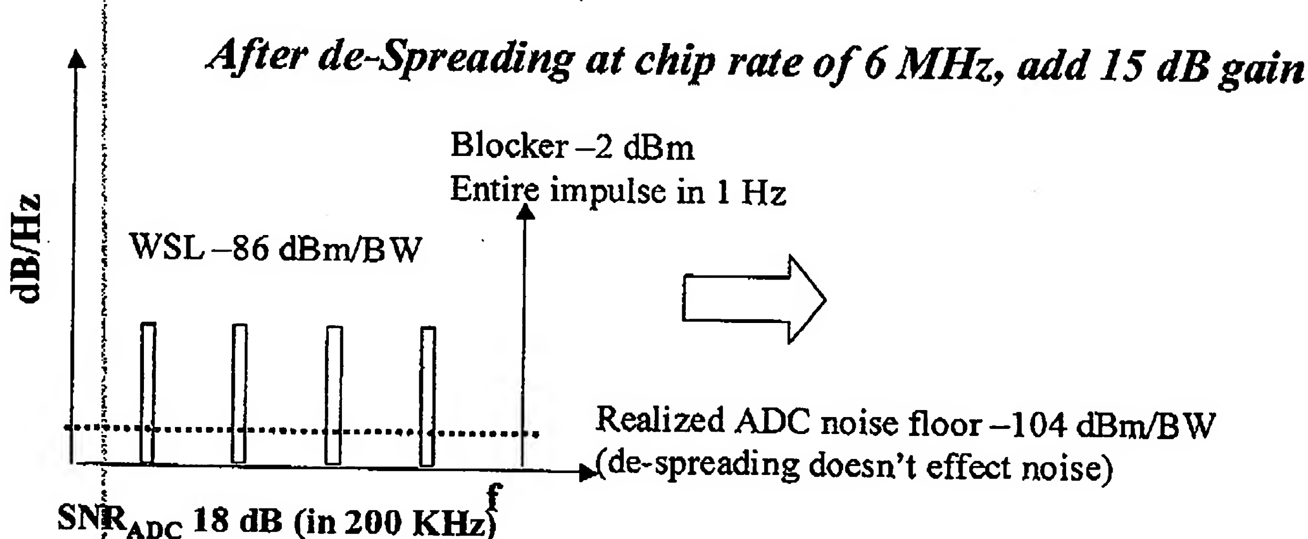

Figure 5d: Example of 5c After De-Spreading [note signals are de-spread but ADC noise is not]

(Please Obtain All Signatures Before Sending to Lorna Schott, Intellectual Asset Management)

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Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
Witnessed, Read and Understood by:		Witness:	Date:	Supervisor:	Date:

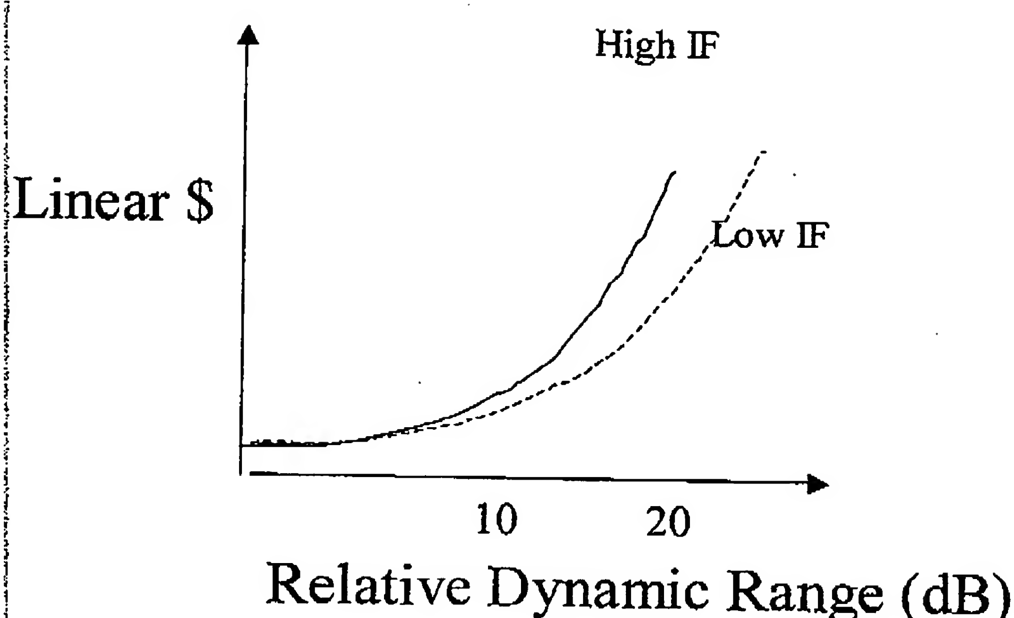

Figure 6: Representation of the Cost of ADCs vs. Dynamic Range

(Please Obtain All Signatures Before Sending to Lorna Schott, Intellectual Asset Management)

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Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
Witnessed, Read and Understood by:		Witness:	Date:	Supervisor:	Date:

Market Evaluation:

Military or Defense applications:

Does the invention have only military or defense applications?

No

TRW applications:

Is the invention used in a current or planned TRW product?

Possibly. It is an option for near-term base station product development.

If Yes, describe the product and expected time to market.

12-24 months

Sales and Licensing Potential -- please fill out this section to the best of your ability. Your answers will help us understand potential markets or licensing opportunities for your invention.

Please describe potential current or future commercial uses for your invention. List specific products that already make use of this invention, or could benefit from the use of it. Be as specific as possible.

Mobile, fixed, airborne, and space-based transmitters.

Are you aware of existing companies that might be interested in license or sale? What companies could benefit from the use of this patent? What companies compete in this technology?

Yes, NOKIA. Ericcson and Motorola are other potential users.

Is your invention easily detected? If a product were to make use of it, what would the process be to verify it?

Visual inspection would be partially revealing but the firmware/digital logic has significant functionality that would be difficult to parse.

What countries should patent applications for this invention be filed in? Why?

US, Europe and Japan are major potential markets. Possibly Korea as well. All of these regions have commercial wireless systems in place or planned that could benefit from the present invention.

Feel free to describe any commercial value or opportunities you feel weren't covered by these questions.

The third embodiment may also prove useful for ultra-wideband communications systems.

NG has wideband and high dynamic range ADCs. The present invention would increase the range of applications to which they could be employed.

The present invention may also be useful for extending the dynamic range of test equipment.

(Please Obtain All Signatures Before Sending to Loma Schott, Intellectual Asset Management)

Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
Inventor:	Date:	Inventor:	Date:	Inventor:	Date:
Witnessed, Read and Understood by:		Witness:	Date:	Supervisor:	Date:

EXIBIT
B

From: Christopher Harris
To: ian.robinson@ngc.com
Date: 10/1/03 2:15PM
Subject: Docket No. 000293-804 (Our Ref: NG(ST)-6583)

Hi Ian,

Attached is a first draft patent application and related drawings in connection with the above-identified disclosure.

Please review the application for technical accuracy and completeness. Additionally, please specifically confirm that the application describes the invention in sufficient detail so as to allow a person having ordinary skill in the art to make and use the invention without undue effort or experimentation. Please confirm that the application describes what you consider to be the best manner for practicing the invention.

This e-mail is also to confirm that you are not aware of any statutory bars (e.g., public disclosure of the invention through printed publication - foreign or domestic, public use of the invention, sale of the invention, or foreign or domestic patent applications relating to the invention) that may have an impact on the patentability of the invention.

I look forward to receiving your comments for revising and/or finalizing the application. If you have any questions, please do not hesitate to contact me.

Best Regards,
Chris Harris

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CC: Christopher Harris

Docket No. NG(ST)-6583

EXHIBIT
C

SYSTEMS AND METHODS FOR SIGNAL CONVERSION

TECHNICAL FIELD

[0001] The present invention relates generally to electronics, and more particularly to systems and methods for signal conversion.

BACKGROUND OF THE INVENTION

[0002] Efforts in the design of communication systems generally focus on improving performance, reducing cost or a combination thereof. One area of increasing interest relates to conversion of signals, such as from analog-to-digital or digital-to-analog. As communications systems become increasingly complex, increased dynamic range and increased resolution is required in the signal conversion process. The expense of signal conversion components increases dramatically with an increase in dynamic range and resolution of the converter.

[0003] Dynamic range describes the range of the input signal levels that can be reliably measured simultaneously and in particularly the ability of a converter to accurately measure small signals in the presence of large signals. The range of signal amplitudes (or signal strengths) a converter can resolve is typically expressed in decibels. A converter with a dynamic range of 60dB means that it can resolve signals in the range in amplitude from x to 1000x. Dynamic range is important in communication applications where signal strengths vary dramatically. For example, if an analog-to-digital converter (ADC), of a particular dynamic range, receives a signal that is too large, the ADC will over-range the ADC input. If the same ADC receives a signal that is too small, the signal will get lost in the quantization noise of the converter.

[0004] The dynamic range of signal conversion components has an upper bound that is limited by the system full scale signal (*e.g.*, peak levels), and a lower bound that is limited by two independent error signals: system noise floor and spurious signals. The dynamic range of a signal conversion component should be higher than the signal-to-noise ratio of the input signal, otherwise, the acquired data is distorted by the signal conversion component. Spurious signals have a higher amplitude than noise, and the amplitude of spurious signals does not depend on the amplitude of the passband. The

main source of spurious signals is caused by non-linearities in the system with the main source being the signal conversion component.

SUMMARY OF THE INVENTION

[0005] The present invention relates to systems and methods for signal conversion. The signal to be processed is spread before processing, and then despread after processing. Processing may include, but is not limited to, digital-to-analog conversion, analog-to-digital conversion, clipping, frequency conversion, and/or filtering.

[0006] Another aspect of the present invention is directed to a system for signal conversion. The system includes a spreader that combines a spreading signal with an input signal to provide a spread input signal. A signal converter converts the spread input signal from a first domain to a second domain to provide a converted spread input signal. A despreader despreads the converted spread input signal to provide the input signal in the second domain.

[0007] According to another aspect of the present invention, a signal conversion system is provided. The signal conversion system includes a spreading code generator that produces a direct sequence spread spectrum (DS-SS) signal. A spreading circuit combines an input signal with the DS-SS signal to provide a spread input signal. A clipping component reduces peaks associated with the spread input signal. A despreading circuit despreads the peak reduced spread input signal.

[0008] According to yet another aspect of the present invention, a method for signal conversion is provided. The method includes spreading a signal with a direct sequence spread spectrum (DS-SS) signal in a first domain, converting the spread signal from the first domain to a second domain, and despreading the signal with a DS-SS signal in the second domain.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. 1 is a block diagram schematically illustrating a system in accordance with an aspect of the present invention.

[0010] FIG 2 is an example graphical illustration of the power spectral density of two signals.

[0011] FIG 3 is an example graphical illustration of the power spectral density of the third order intermodulations (IM) of the signals of FIG. 2.

[0012] FIG 4 is an example graphical illustration of the power spectral density of the two signals of FIG. 2 after spreading.

[0013] FIG 5 is an example graphical illustration of the power spectral density of the third order intermodulations of the signals of FIG. 4.

[0014] FIG 6 is a graphical illustration of the power spectral density of the two signals of FIG 2 after spreading.

[0015] FIG. 7 is a graphical illustration of the power spectral density of the two signals of FIG 6 after 10 dB of despreading gain is applied.

[0016] FIG 8 is a graphical illustration of the power spectral density of the third order intermodulations after spreading the signals of FIG. 4.

[0017] FIG 9 is a graphical illustration of the power spectral density of the third order intermodulations of the signals of FIG. 6 after 10 dB of despreading gain is applied.

[0018] FIG. 10 is a block diagram schematically illustrating a receiver circuit in accordance with an aspect of the present invention.

[0019] FIG. 11 is a functional block diagram of a digital processor in accordance with an aspect of the present invention.

[0020] FIG 12 is a block diagram schematically illustrating a signal processing circuit in accordance with an aspect of the present invention.

[0021] FIG. 13 is a block diagram schematically illustrating a transmitter circuit in accordance with an aspect of the present invention.

[0022] FIG. 14 is a block diagram schematically illustrating a transmitter circuit in accordance with another aspect of the present invention.

[0023] FIG. 15 is a block diagram schematically illustrating a transmitter circuit in accordance with yet another aspect of the present invention.

[0024] FIG 16 is a block diagram schematically illustrating a transmitter circuit with a delta-sigma digital-to-analog converter (DAC) in accordance with another aspect of the present invention.

[0025] FIG 17 is a block diagram of a method for signal conversion in accordance with an aspect of the present invention.

[0026] FIG 18 is a block diagram of a method for signal conversion in accordance with another aspect of the present invention.

[0027] FIG 19 is a block diagram of a method for signal conversion in accordance with yet another aspect of the present invention.

[0028] FIG 20 is a block diagram of a method for signal conversion in accordance with yet a further aspect of the present invention.

DETAILED DESCRIPTION OF INVENTION

[0029] The present invention relates generally to systems and methods for signal conversion. Input signals which may be analog or digital are spread with spread codes (*e.g.*, Pseudo Random codes, Pseudo Noise codes) to provide a spread spectrum signal (*e.g.*, a direct sequence spread spectrum (DS-SS) signal). The signals are then converted from a first domain (*e.g.*, digital, analog) to a second domain (*e.g.*, analog, digital) *via* a signal converter. The converted signal is then despread using substantially the same codes as used to spread the signal. The spreading codes to provide the spreading code signal can be selected from a variety of spread spectrum standards or a combination of spread spectrum standards. For example, the spreading signal can be a DS-SS signal, which can also be combined with a frequency hopped spread spectrum (FH-SS) signal.

[0030] The spreading prior to signal conversion and the despreading subsequent to signal conversion reduces linearity requirements in signal conversion devices in addition to transmit and receive chains in which the signal converters may be employed. Reduced linearity is desirable because it enables lower cost, lower dynamic range and less complex components such as amplifiers, frequency conversion components, ADCs and DACs. Therefore, an improved dynamic range system can be provided with lower dynamic range devices.

[0031] Additionally, a greater range of frequency plans can be employed. For example, many ADCs provide maximum performance at low IF, which can require a double down-conversion. Unfortunately, double down conversion architectures produce a large number of spurs. To accept these spurs, highly linear components are necessary. The signal conversion technique of the present invention enables lower dynamic range signal converters to be employed since the signal is spread out over a larger bandwidth with lower amplitudes. Additionally, spurs and unwanted noise are filtered during the despreading process because the spurs and unwanted noise are spread over a wide range of frequencies while the desired signal is despread.

[0032] FIG. 1 illustrates a signal conversion system 10 in accordance with an aspect of the present invention. The signal conversion system 10 employs spreading and despreading techniques to improve dynamic range associated with signal conversion. The signal conversion system includes a spreader 12. The spreader 12 generates spreader codes (*e.g.*, Pseudo Random codes, Pseudo Noise codes) to provide a spread spectrum signal (*e.g.*, a DS-SS signal, a DS-SS signal combined with FH-SS signal). The spreader 12 combines the spread spectrum signal with an input signal to provide a spread input signal. The input signal can be a single or multi-carrier signal. For example, the input signal can conformed to a wireless standard such as Wideband Code Division Multiple Access (WCDMA), Orthogonal Frequency Division Multiplexing (OFDM), and multi-carrier versions of Global Standard for Mobile Communication (GSM) and Code Division Multiple Access 2000 (CDMA 2000). Signals that conform to WCDMA, multi-carrier GSM, OFDM or other signals having similar noise like signatures have high peak-to-average (PAR) ratios. The present invention spreads these signals such that the amplitudes are reduced so that lower dynamic range signal converters can be employed.

[0033] A signal converter 14 receives the spread input signal and converts the spread input signal from a first domain to a second domain. For example, the first domain can be an analog domain and the second domain can be a digital domain. Alternatively, the first domain can be a digital domain and the second domain can be an analog domain. The signal converter 14 can have a dynamic range that enables conversion of signals with amplitude peaks of the spread input signal. These amplitude

peaks are substantially lower than the amplitude peaks of the original input signal, thus allowing for employment of a signal converter 14 with reduced linearity and lower dynamic range.

[0034] The converted spread input signal is then provided to a despreader 16. The despreader 16 despreads the converted spread input signal with substantially the same codes (*e.g.,* Pseudo Random codes, Pseudo Noise codes) as the spreader 12. The despreader 16 despreads the converted spread input signal and provides an output signal corresponding to the original input signal in the second domain. For example, if the input signal is analog, the output signal is digital. If the input signal is digital, the output signal is analog. The despreader 16 also removes spurs and unwanted noise since spurs and unwanted noise are filtered during the despreading process because the spurs and unwanted noise are spread over a wide range of frequencies, while the desired signal is despread. Optionally, a feedback or feedforward signal 18 may be provided to facilitate time alignment or synchronization.

[0035] While the conversion system 10 of FIG 1 has been described as converting from one domain to another (*e.g.,* digital to analog), as those skilled in the art can readily appreciate the present invention can also be used for signal conversion within the same domain. For example, signal converter 14 may be a mixer for frequency conversion, either up conversion or down conversion, a clipping circuit, amplifier, and/or a filter. The signal converter 14 may also comprise a plurality of converters, for example a digital signal may be clipped, converted to analog, and up converted.

[0036] It is to be appreciated that the present invention reduces linearity requirements in transmit and receive chains. Reduced linearity is desirable because it enables lower cost and less complex components such as amplifiers, frequency conversion components, ADCs and DACs to be used. A greater range of frequency plans can be employed. For example, many ADCs provide their best performance at low IF, which can require a double down-conversion. Unfortunately, double down conversion architectures produce a large number of spurs. To accept these spurs, highly linear components are necessary.

[0037] To understand one of the benefits of spreading, assume there are two modulated carriers, $s_1(t)=A(t)\cos[\omega_1 t+\Phi_1(t)]$ and $s_2(t)=B(t)\cos[\omega_2 t+\Phi_2(t)]$. These carriers are received by a signal chain with a non-linearity which can be modeled as having an output O(t), proportional to the cube of the input; $O(t) \sim (s_1+s_2)^3$. If A and B are the same, then $O \sim s_1^3+s_2^3+3s_1^2 s_2+3s_2^2 s_2$. The non-linearity can result from a mixer, amplifier, ADC, DAC, and/or any other component.

[0038] The terms $3s_1^2 s_2+3s_2^2 s_2$ are the third-order intermodulation (IM) terms, centered at $2\omega_2- \omega_1$ and $2\omega_1- \omega_2$. The IM magnitudes are proportional to $\cos[\omega_1 t+\Phi_1(t)]^2\cos[\omega_2 t+\Phi_2(t)]$ and $\cos[\omega_2 t+\Phi_2(t)]^2\cos[\omega_1 t+\Phi_1(t)]$, respectively. In the frequency domain each time-domain multiplication is a convolution. Thus each third-order IM is proportional to the convolution of each signal with itself (the squared terms) and then with the other signal, $s_1*s_1*s_2$ and $s_2*s_2*s_1$.

[0039] FIG. 2 illustrates s_1 and s_2 without spreading, and FIG. 4 illustrates s_1 and s_2 with spreading. The two set of signals have the same integrated power but at different power densities. The diagrams are notional but represent ~10 dB of spreading. The y-axis of FIGS. 2-9 illustrates relative signal levels and are intended to show the impact of the spreading on the original signals and the IMs.

[0040] FIGS. 3 and 5 illustrate the results of the convolution of the signals of FIGS. 2 and 4, respectively. FIGS. 3 and 5 illustrate that The IM's have wider bandwidth than the original signals (note if s_1 and s_2 are tones or BPSK modulation then their IMs will have the same bandwidth as the original signals).

[0041] One aspect illustrated in FIGS. 3 and 5 is that the amplitude of the IM products with spreading (FIG. 5) is ~ 30 dB lower than the IMs from the unspread signals (FIG. 3). This is because the convolution, the sum or integral of the products of the signals as they are 'slid' past each other, has a level proportional to the cube of the peak of the original signals. The spreading decreases the wanted signals by ~10 dB and the third order IMs by ~30 dB.

[0042] Another feature illustrated by FIGS. 3 and 5 is that the spread IMs (FIG. 5) occupy approximately 10 times the bandwidth of the IMs resulting from the unspread signals (FIG 3). Another aspect of spreading which is not evident in FIGS. 3 and 5 is

that the spread signal of the IMs may not be coherent with the spreading code used on the original signals.

[0043] FIGS. 6-9 illustrates the signals and the resulting IM levels after ~10 dB of despreading gain is applied to the signals illustrated in FIG 2. The signals are compressed by 10 dbB (10x) in bandwidth (FIG. 6). The original signals are fully recovered at their original signal levels (FIG. 7). However, the IM products which were reduced ~30 dB due to spreading are despread to a level ~20 dB below the level of the IM products without the spreading (note the scale of the y-axis of FIG. 9 compared to FIG. 3), which improves the level of non-linearity. The IM improvement in dB is roughly 10logR(I-1), where R is the spreading gain (spread signal bandwidth/unspread bandwidth) in dB and I is the order of the intermodulation product or spur. Higher order IMs show greater reduction in power levels.

[0044] The wide bandwidth of the IMs when spreading is used introduces the possibility of filtering some of the IM power before despreading, as it is likely that some of the power will be spread outside of the band of interest. If filtering can be applied before despreading then the relative IM power will be reduced.

[0045] It is also possible that full despreading gain will not be applied to the IMs. The despreading gain is maximized when there is a substantial correlation between the signal of interest (spread with a code) and the despreading using the same code. Since IMs are inherently a non-linear product of the signals occupying a much different bandwidth (and accordantly different temporal properties), they may not be able to line-up or correlate with the code. Any imperfection in despreading of the IM products maintains them at a wider bandwidth with lower power density in most bandwidths.

[0046] Without filtering or imperfect despreading there is a reduction in non-linear products. This reduction allows either much higher performance of the receive chain or a significant relaxation of the linearity of all of the components located between the spreading and despreading functions.

[0047] FIG. 10 illustrates a receiver circuit 200 that employs spreading prior to analog to digital conversion in accordance with an aspect of the present invention. The receiver circuit 200 employs digital spreading codes that provide a digital spread spectrum signal that can be combined with an input signal of an ADC 214. The

spreading code is converted to an analog signal by a DAC 220 and mixed with an analog input signal before it is converted to the digital domain by the ADC 214.

[0048] A signal is received by an antenna 202 and filtered by a bandpass filter 204. The output of bandpass filter 204 is amplified by an amplifier 206. The output of the amplifier 206 is connected to a first input of a mixer 208. A second input of the mixer 208 is connected to local oscillator 210, producing an IF signal at an output of the mixer 208. The IF signal is provided to a first input of a mixer 212 and spread by an analog spreading signal 222. The spread IF signal is then converted to the digital domain by the ADC 214.

[0049] The digital spread IF signal is provided to a digital processor 216 where it is despread using substantially the same digital spread spectrum signal used to spread the signal. Digital processor 216 time aligns the despreading of the digital spread IF signal to provide a baseband output signal. Digital processor 216 produces the spreading signal 218. The spreading signal is converted to the analog domain, *via* DAC 220, into an analog spreading signal 222. The spread spectrum signal 218 can be a direct sequence, a frequency hopped, or a combination of discrete sequence and frequency hopped spread spectrum signal.

[0050] Referring to FIG. 11 with continued reference to FIG. 10, there is schematically illustrated the functional components of digital processor 216. The digital processor 216 comprises spread code generator 252, and correrlator 254. Correlator 254 receives input signal 256 from ADC 214 and spread code signal 218 from spread code generator 252. Correlator 254 time aligns and despreads signal 256. Spread code signal 218 is also provided to DAC 220 to provide spread code to spread the analog IF signal from the mixer 208. Although FIG 11 illustrates the digital processor 216 having a spread signal code generator 252 and correlator 254, those skilled in the art can readily appreciate, any or all of these functions may be performed by circuits external to the digital processor 216, and/or software algorithms executed by the digital processor 216, and the examples presented herein should not be construed as limited to these functions being performed by a digital processor. Alternatively, a time delay (not shown) can be used to synchronize the spreading and despreading circuits which may eliminate the need for correlator 254 to perform the time alignment.

[0051] Referring now to FIG. 12 there is schematically illustrated a system 300 with a delta sigma ADC 306 in accordance with another aspect of the present invention. Delta Sigma modulation is a technique used to generate a coarse estimate of a signal using a small number of quantization levels and a very high sampling rate. The small number (two for a one-bit quantizer) of quantization levels introduces "quantization" noise into the system. The effect of oversampling and the use of an integrator feedback-loop in delta-sigma modulation are effective in shifting noise to out-of-band frequencies. The noise shifting properties and introduction of quantization error enables efficient use of subsequent filtering stages to remove noise and produce a more precise representation of the input at a much higher frequency. Delta sigma DACs can be employed to upconvert the input signal directly to radio transmission frequencies, such that further frequency conversion of the signals *via* conventional mixers is not required. The radio transmission frequencies can be in radio frequency (RF) ranges (*e.g.*, megahertz range) or in microwave frequency ranges (*e.g.*, gigahertz range). Delta sigma ADCs can be employed to downconvert the input signal directly from radio transmission frequencies to intermediate frequencies, such that further frequency conversion of the signals *via* conventional mixers is not required.

[0052] Digital processor 308 produces a spreading signal 310 that is sent to DAC 312 and converted to an analog spreading signal 314. Mixer 304 mixes an input signal 302 with the analog spreading signal 314. The spread analog input signal is sent from mixer 304 to delta-sigma ADC 306. The output of the delta-sigma ADC 306 is input into the digital processor 308 for despreading and other functions such as time alignment.

[0053] FIG. 13 illustrates a transmitter circuit 400 in accordance with an aspect of the invention. The transmitter circuit 400 spreads a digital signal *via* a spreading code, converts the spread digital signal to the analog domain, and up converts the spread analog signal before despreading. The transmitter circuit 400 includes a digital processor 404 that receives a digital input signal 402 and spreads the digital input signal 402 with a spreading signal generated by a spreading code generator 416. Although spreading code generator 416 is shown as a separate element, it can also be a part of digital processor 404. The spread digital input signal is provided to DAC 406 which converts the spread digital input signal to the analog domain to provide a spread analog

signal. The spread analog signal is then filtered by filter 408. The filtered spread analog signal is provided to mixer 410 whereupon it is mixed with local oscillator 412 for frequency conversion. After frequency conversion, the signal is sent to mixer 414 where it is despread by mixing with the spreading signal from the spreading code generator 416. The despread signal is subsequently filtered by filter 418, amplified by amplifier 420 and transmitted *via* antenna 422.

[0054] FIG. 14 illustrates a transmitter circuit 500 that employs clipping in accordance with an aspect of the present invention. Existing techniques to reduce peak-to-average ratios (PAR) are content with the resultant degradations to wanted signals (characterized by EVM) and out-of-band (OOB) emissions. The present invention employs spreading and dispreading techniques to mitigate the resultant degradation and OOB emissions caused by clipping. The transmitter circuit 500 includes a digital processor 504 that mixes an input signal with a spreading signal (not shown) produced by spreading code generator 516. Spreading code generator 516 may be a separate circuit as shown or can be a module within digital processor 504. After spreading, the signal is clipped by clip filter 524 and then converted to the analog domain by DAC 506, and subsequently filtered by filter 508. The clipping filter 524 can be a soft or hard clipping filter. Additionally, the clipping filter 524 can perform a fixed or shape limiting algorithm to reduced the peaks and peak-to-average ratio (PAR) associated with the spread input signal. The signal is then frequency converted by mixer 510 with local oscillator 512. The output of mixer 510 is then input into mixer 514. Another input of mixer 514 receives the spreading code in the analog domain from spreading code generator 516 and the signal is then despread. Subsequently, the signal is filtered by filter 518, amplified by amplifier 520 and transmitted *via* antenna 522.

[0055] FIG. 15 is a transmitter circuit 600 in accordance with yet another aspect of the present invention. The transmitter circuit 600 is operative to spread an input signal, clipped the spread input signal and despread the clipped spread input signal prior to digital to analog conversion. The transmitter circuit 600 includes a digital processor 604 that receives signal 602 and spreads the signal 602 with a spreading signal 610. Spreading signal 610 may be generated by digital processor 604, or may be

provided by an external spreading code generator (not shown). The output of the digital processor is input into clip filter 606. The clip filter 606 reduces the peaks and PAR associated with the spread input signal. The output of clip filter 60 is then input into a mixer 608 which receives spreading signal 610 from digital processor 604 and functions as a despreading circuit. Digital processor 604 would also handle any time alignment or synchronization required for despreading. The clipped and despread signal is sent from mixer 608 to DAC 612 where it is converted to an analog signal. The analog signal is filtered by filter 614 and then frequency converted by mixer 616 which mixes the filtered signal with a signal from a local oscillator 618. The frequency converted signal is then filtered by filter 620, amplified by amplifier 622 and subsequently transmitted *via* antenna 624.

[0056] FIG. 16 illustrates a transmitter circuit 700 that employs a delta-sigma DAC in accordance with an aspect of the present invention. A delta-sigma DAC can be employed to upconvert the input signal directly to radio transmission frequencies, such that further frequency conversion of the signals *via* conventional analog mixers is not required. The radio transmission frequencies can be in radio frequency (RF) ranges (*e.g.*, megahertz range) or in microwave frequency ranges (*e.g.*, gigahertz range). The transmitter circuit 700 includes a digital processor 704 that receives and spreads an input signal 702. The spread signal is clipped by clip filter 706. The clipped signal is then despread *via* mixer 708, which receives the signal from clip filter 706 and the spreading signal 710 from digital processor 704. The despread signal from mixer 708 is input into a delta-sigma DAC 712. The output of the delta-sigma DAC 712 is input into amplifier 714 for amplification and is subsequently transmitted *via* antenna 716.

[0057] Another aspect of the present invention is directed to methods for processing a signal. While, for purposes of simplicity of explanation, a methodology is shown and described as executing serially, it is to be understood and appreciated that the present invention is not limited by the order shown, as some aspects may, in accordance with the present invention, occur in different orders and/or concurrently from that shown and described herein. Moreover, not all features shown or described may be needed to implement a methodology in accordance with the present invention. Additionally, such methodology can be implemented in hardware (*e.g.*, one or more

integrated circuits), software (*e.g.*, running on a DSP or ASIC) or a combination of hardware and software.

[0058] FIG. 17 illustrates a method 800 for signal conversion in accordance with an aspect of the present invention. The methodology begins at 802 where a signal is received. The signal is then filtered at 804 and amplified at 806. At 808, the signal is converted to IF, for example, via mixing with a mixer. At 810, the converted IF signal is spread *via* a spreading code. The signal can be spread *via* direct sequence spread spectrum (DS-SS), frequency hopped spread spectrum (FH-SS), a combination of DS-SS and FH-SS, or other spreading technique. For DS-SS, the spreading signal can be continuous in the frequency domain. The signal is then converted from the analog domain to the digital domain at 812. At 814, the signal is despread using substantially the same spreading code for spreading. However, the despreading signal is converted from the digital domain to the analog domain prior to despreading. Furthermore, time synchronization, if necessary, can be employed during spreading and/or dispreading.

[0059] FIG. 18 illustrates another methodology 900 for signal conversion in accordance with an aspect of the present invention. The method 900 includes a frequency conversion and digital to analog signal conversion. A digital signal is spread at 902 using any of the aforementioned spreading techniques. At 904, the digital spread signal is converted to the analog domain, and the analog spread signal is filtered at 906. At 908, the signal is converted to a different frequency *via* frequency conversion. At 910, the signal is despread using substantially the same spreading code for spreading. However, the despreading signal is converted from the digital domain to the analog domain prior to despreading. Furthermore, time synchronization, if necessary, can be employed during spreading and/or despreading.

[0060] FIG. 19 illustrates a signal conversion method 1000 that includes clipping and frequency conversion in accordance with another aspect of the present invention. At 1002, an input signal is spread utilizing any of the aforementioned spreading techniques. At 1004, the signal is clipped using a clipper or limiter. At 1006, the signal is converted from the digital domain to the analog domain, and then filtered at 1008. At 1010, the signal is frequency converted. At 1012, the signal is despread using substantially the same spreading code for spreading. However, the despreading signal

is converted from the digital domain to the analog domain prior to despreading. Furthermore, time synchronization, if necessary, can be employed during spreading and/or despreading. At 1012 the signal is despread. At 1014 the signal is filtered. At 1016 the signal is amplified and transmitted at 1018.

[0061] FIG. 20 illustrates yet another signal conversion method 1100 in which the clipping is performed on a spread signal in accordance with an aspect of the present invention. At 1102, a signal is spread using any of the aforementioned spreading techniques. The spread signal is clipped at 1104, for example, employing a clipping filter or other peak reduction technique. At 1106, the signal is despread using substantially the same signal as was used for spreading. The despreading may need to be time aligned, which can also occur at 1106. At 1108, the signal is converted to the analog domain and frequency converted at 1110. For transmitting, the signal can be up converted. However, the signal may be down converted if desired. At 1112, the signal is transmitted.

[0062] What has been described above includes exemplary implementations of the present invention. It is, of course, not possible to describe every conceivable combination of components or methodologies for purposes of describing the present invention, but one of ordinary skill in the art will recognize that many further combinations and permutations of the present invention are possible. Accordingly, the present invention is intended to embrace all such alterations, modifications and variations that fall within the spirit and scope of the appended claims.

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CLAIMS

What is claimed is:

1. A system for signal conversion, comprising:

a spreader that combines a spreading signal with an input signal to provide a spread input signal;

a signal converter that converts the spread input signal from a first domain to a second domain to provide a converted spread input signal; and

a despreader that despreads the converted spread input signal to provide the input signal in the second domain.

2. The system of claim 1, further comprising a spreading code generator that produces spreading codes to provide a direct sequence spread spectrum (DS-SS) spreading signal.

3. The system of claim 2, the spreading code generator further produces a frequency hopped spread spectrum (FH-SS) signal that is combined with the DS-SS spreading signal.

4. The system of claim 1, further comprising a spreading code generator that generates a pseudo random number code to provide a spreading signal.

5. The system of claim 1, further comprising a feedback loop coupling the despreader to the spreader for time aligning the despreading with the spreading.

6. The system of claim 1, wherein the first domain is one of a digital domain and an analog domain and the second domain is the other of the digital domain and the analog domain.

7. The system of claim 1, further comprising a mixer for frequency converting the spread input signal prior to dispreading.

8. The system of claim 1, wherein the signal converter is one of a delta-sigma analog-to-digital converter (ADC) and a delta-sigma digital-to-analog converter (DAC).

9. The system of claim 1, further comprising a clipping component that reduces peaks associated with the spread input signal, the despreader mitigates degradation and out-of-band (OOB) emissions associated with the peak reduction.

10. The system of claim 1, wherein at least one of the spreader and the despreader circuit comprises a mixer.

11. A receiver comprising the system of claim 1.

12. A transmitter comprising the system of claim 1.

13. A signal conversion system comprising:

a spreading code generator that produces a direct sequence spread spectrum (DS-SS) signal;

a spreading circuit that receives an input signal and combines the input signal with the DS-SS signal to provide a spread input signal;

a clipping component that reduces peaks associated with the spread input signal; and

a despreading circuit that despreads the peak reduced spread input signal.

14. The system of claim 13, wherein at least one of the spreading circuit and despreading circuit comprises a mixer.

15. The system of claim 13, further comprising a signal converter that converts the spread input signal from a first domain to second domain, the signal converter being one of a digital-to-analog converter (DAC) and an analog-to-digital converter (ADC).

16. The system of claim 15, the signal converter being one of a delta-sigma DAC and a delta-sigma ADC.

17. The system of claim 15, further comprising a second signal converter for converting the spread signal from the second domain to the first domain.

18. The system of claim 15, further comprising a mixer for frequency converting the spread input signal one of before signal conversion and after signal conversion.

19. A method for signal conversion, comprising:

spreading a signal with a direct sequence spread spectrum (DS-SS) signal in a first domain;

converting the spread signal from the first domain to a second domain; and

despreading the signal with a DS-SS signal in the second domain.

20. The method of claim 19, further comprising spreading and despreading the signal with a frequency hopped spread spectrum (FH-SS) signal.

21. The method of claim 19, wherein the first domain is one of a digital domain and an analog domain and the second domain is the other of the digital domain and the analog domain.

22. The method of claim 19, further comprising frequency converting the signal to an intermediate frequency.

23. The method of claim 19, further comprising:
receiving the signal from an antenna;
filtering the signal;
amplifying the signal; and
converting the signal to an intermediate frequency signal prior to spreading the signal.

24. The method of claim 19, further comprising:
converting the signal to a radio transmission frequency;
filtering the signal;
amplifying the signal; and
transmitting the signal over an antenna

25. The method of claim 19, further comprising clipping the signal to reduce peaks associated with the signal.

26. A communication device comprising:
means for generating a direct sequence spread spectrum (DS-SS) signal;
means for combining the DS-SS signal with an input signal to produce a spread input signal;
means for converting the spread input signal from a first domain to a second domain; and
means for dispreading the spread input signal in the second domain.

27. The device of claim 26, further comprising means for removing peaks from the spread input signal.

SYSTEMS AND METHODS FOR SIGNAL CONVERSION

ABSTRACT

Systems and methods for signal conversion are provided. Signals are spread in a continuous spectrum by a spread spectrum signal, such as a direct sequence spread spectrum (DS-SS) signal. The signals are then processed, which may include but is not limited to analog-to-digital conversion, digital-to-analog conversion, frequency conversion, clipping, filtering or a plurality of processes. The processed signal is then despread using substantially the same spreading signal that was used to spread the signal.

EXHIBIT

D

From: Christopher Harris
To: ian.robinson@ngc.com
Date: 10/7/03 9:21AM
Subject: Docket No. 000293-804 (Our Ref: NG(ST)-6583)

Hi Ian,

Attached is a second draft patent application and related drawings in connection with the above-identified disclosure. I also provided you with a redline version.

Please review the application for technical accuracy and completeness. Additionally, please specifically confirm that the application describes the invention in sufficient detail so as to allow a person having ordinary skill in the art to make and use the invention without undue effort or experimentation. Please confirm that the application describes what you consider to be the best manner for practicing the invention.

I look forward to receiving your comments for revising and/or finalizing the application. If you have any questions, please do not hesitate to contact me.

Best Regards,
Chris Harris

Christopher P. Harris
Tarolli, Sundheim, Covell & Tummino, L.L.P.
526 Superior Avenue,
Suite 1111
Cleveland, OH 44114-1400
Phone: (216) 621-2234 x104
Fax: (216) 621-4072
Email: charris@tarolli.com

CC: Larry B. Donovan; Leslie Kuder

EXHIBIT
E

From: <ian.robinson@ngc.com>
To: <charris@tarolli.com>
Date: 10/7/03 3:46PM
Subject: RE: Docket No. 000293-804 (Our Ref: NG(ST)-6583)

Hi Chris,
The revised text you sent is good to go.

FIGS 2,4, 6, and 7 should be omega not f. FIGS 3 and 9 should have the same shape.

Please send final clean versions to me.
Thx.
Ian

-----Original Message-----
From: Christopher Harris [mailto:charris@tarolli.com]
Sent: Tuesday, October 07, 2003 12:11 PM
To: Robinson, Ian
Cc: Larry B. Donovan; Leslie Kuder
Subject: RE: Docket No. 000293-804 (Our Ref: NG(ST)-6583)

Hi Ian,
Changes to the Figures were as follows:
Figs 3-5,7 and 9 had the x axis changed to omega.
The first mixer was removed from Figs 10 and 13.
The mixer of Fig 15 was changed to a despreader.

The redline application corresponds to changes between version one and version 2 of the application.

Attached is a redline that corresponds to changes to your incorporated comments with limiting and definite terminology removed or modified.

If you have any questions, please do not hesitate to contact me.

Best Regards,
Chris Harris

Christopher P. Harris
Tarolli, Sundheim, Covell & Tummino, L.L.P.
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Cleveland, OH 44114-1400
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any use, dissemination, distribution or
copying of this document or its contents
is strictly prohibited.
****

>>> <ian.robinson@ngc.com> 10/07/03 01:26PM >>>
Hi Chris,
It appears that you sent me back the exact same word file I sent you. Is this correct?

I can't tell what was done, if anything, on the visio file but it doesn't appear that you addressed my comments.

Please confirm.
Thx.
Ian

-----Original Message-----
From: Christopher Harris [mailto:charris@tarolli.com]
Sent: Tuesday, October 07, 2003 6:22 AM
To: Robinson, Ian
Cc: Larry B. Donovan; Leslie Kuder
Subject: Docket No. 000293-804 (Our Ref: NG(ST)-6583)

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Best Regards,
Chris Harris

Christopher P. Harris
Tarolli, Sundheim, Covell & Tummino, L.L.P.
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Suite 1111
Cleveland, OH 44114-1400
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Email: charris@tarolli.com

****
This transmission contains confidential

From: Christopher Harris
To: "ian.robinson@ngc.com".GWIA.TAROLLI
Date: 10/7/03 3:10PM
Subject: RE: Docket No. 000293-804 (Our Ref: NG(ST)-6583)

Hi Ian,
Changes to the Figures were as follows:
Figs 3-5,7 and 9 had the x axis changed to omega.
The first mixer was removed from Figs 10 and 13.
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The redline application corresponds to changes between version one and version 2 of the application.

Attached is a redline that corresponds to changes to your incorporated comments with limiting and definite terminology removed or modified.

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Best Regards,
Chris Harris

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Suite 1111
Cleveland, OH 44114-1400
Phone: (216) 621-2234 x104
Fax: (216) 621-4072
Email: charris@tarolli.com

>>> <ian.robinson@ngc.com> 10/07/03 01:26PM >>>
Hi Chris,
It appears that you sent me back the exact same word file I sent you. Is this correct?

I can't tell what was done, if anything, on the visio file but it doesn't appear that you addressed my comments.

Please confirm.
Thx.
Ian

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-----Original Message-----
From: Christopher Harris [mailto:charris@tarolli.com]
Sent: Tuesday, October 07, 2003 6:22 AM
To: Robinson, Ian
Cc: Larry B. Donovan; Leslie Kuder
Subject: Docket No. 000293-804 (Our Ref: NG(ST)-6583)

Hi Ian,

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Best Regards,
Chris Harris

Christopher P. Harris
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CC: Larry B. Donovan; Leslie Kuder

EXHIBIT

tabbles'

F

From: Christopher Harris
To: Ian.robinson@ngc.com
Date: 10/14/03 8:06AM
Subject: Docket No. 000293-804 (Our Ref: NG(ST)-6583)

Hi Ian,

We are also enclosing formal papers (Assignment and Combined Declaration and Power of Attorney) in connection with the above-identified final draft patent application. Also enclosed is a final draft of the application and drawings.

Frank Winter was already sent formal papers on October 8, 2003.

Please execute the attached Declaration and Assignment papers by signing and dating them in the spaces provided. Also note that the Assignment must be dated twice with the declaration execution date and the assignment date. Accordingly, please write the date of your signatures in both blanks on the Assignment.

Please return the originally executed formal papers (Assignment and Declaration) to us for prompt filing with the U.S. Patent and Trademark Office.

If you have any questions or comments regarding this matter, please call us immediately.

Best Regards,
Chris Harris

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CC: Leslie Kuder

EXHIBIT
G

From: Christopher Harris
To: frank.winter@ngc.com
Date: 10/8/03 4:04PM
Subject: Docket No. 000293-804 (Our Ref: NG(ST)-6583)

Hi Ian and Frank,

We are also enclosing formal papers (Assignment and Combined Declaration and Power of Attorney) in connection with the above-identified final draft patent application. Also enclosed is a final draft of the application and drawings.

Please execute the attached Declaration and Assignment papers by signing and dating them in the spaces provided. Also note that the Assignment must be dated twice with the declaration execution date and the assignment date. Accordingly, please write the date of your signatures in both blanks on the Assignment.

Please return the originally executed formal papers (Assignment and Declaration) to us for prompt filing with the U.S. Patent and Trademark Office.

If you have any questions or comments regarding this matter, please call us immediately.

Best Regards,
Chris Harris

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CC: Leslie Kuder